Metal Interconnects for Solid Oxide Fuel Cell Power Systems

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Objectives

- Develop a coating technology for commercial stainless steels for use as interconnect material in solid oxide fuel cells.
- Verify the performance characteristics of the coated materials for corrosion (oxidation) resistance and interfacial electrical resistance at target operating temperature range.

Key Milestones

- A commercially available ferritic stainless steel was selected for evaluation.
- Two promising surface treatment conditions were selected to obtain controlled growth of oxidation scales in cathode atmosphere.
- Low interfacial resistance of less than 10 milliohm-cm^2 was demonstrated both in anode and cathode environments.
- Up to three thermal cycles were demonstrated in metal coupon tests with negligible change in interfacial resistance.

Approach

Prior work performed at Ceramatec Inc. has shown the potential of inexpensive commercial alloys for use in metal interconnects. Technical barriers that exist in the use of metal interconnects include stabilization of oxide scale growth at the fuel cell operating temperature, and the ability to thermal cycle the fuel cell stack with negligible change to the cell — interconnect interfacial properties. The Phase I work extends prior development efforts to address these issues. Scale modifications that are atmosphere appropriate have been developed to stabilize the scale, as well as impart low interfacial electrical resistance. Coating techniques to apply a conductive layer on the modified scale to enhance both chemical and electrical stability were investigated. Initial evaluation included testing of interfacial resistance as a function of time, both in air and fuel atmospheres, at the targeted operating temperature range. The various surface treatment and coating processes were evaluated using coupons from commercial ferritic stainless steel to determine the oxide scale growth and interfacial electrical resistance with time at temperature. The change in interfacial resistance was also monitored as a function of thermal cycles.

Results

The Phase I project focused primarily on the characterization of alloy surface for oxidation scale growth and electrical properties. Both microstructural and electrical characterization techniques were used to identify appropriate surface treatment and coating methods. The results to-date are summarized below.

Alloy Selection: A commercially available ferritic stainless steel was selected for evaluation. The basic criteria used for the selection are: thermal expansion compatibility with cell components (crucial for thermal cycle capability), conductive chromia scale former (required for interface conductivity), low impurity content (to provide chemical compatibility) and commercial availability.

Surface Treatment Process Development and Characterization: Two types of surface treatment conditions were used to obtain controlled growth of oxidation scales. Treated metal coupons showed significantly slower oxide scale growth, as determined by weight gain measurements at test temperature, and by microscopy.

Evaluation of Conductive Coating Methods: Several commercial techniques are being evaluated to apply a conductive layer on the pre-treated alloy coupons. The techniques evaluated include screen printing and thermal spray techniques. The application of a conductive layer on the scale is expected to provide a low in-plane resistance and present a barrier for vapor-phase migration of alloying elements that are known to poison the electrode activity. Measurements in fuel atmosphere after the application of a conductive layer provides an interfacial resistance as low as one milliohm-cm^2 at 750^{o}C stable over the 100-hour test duration. Subsequent thermal cycles between 750^{o}C and room temperature showed only a small increase in resistance, which decayed again to less than one milliohm-cm^2. The electrical resistance test results in humidified hydrogen are shown in Figure 1.

A similar test in air with an appropriate conductive coating also showed very promising results. The interfacial resistance measured was less than 10 milliohm-cm^2 at 750 °C, as shown in Figure 2. Very little change in resistance was noted with one thermal cycle, for two different pre-treatment conditions. Additional thermal cycle evaluations are underway.

Evaluation in Wet Air: The properties of oxide scale is known to change when exposed to humidified air as well as when the two sides of the alloy are exposed to air and fuel atmospheres [1, 2]. The pre-treatment conditions that showed very low scale resistances also showed the lowest oxide scale growth in humidified air.

Conclusions

Phase I results summarized above indicate the potential for using inexpensive commercial ferritic stainless steel as interconnects for solid oxide fuel cells by appropriate surface modifications. Very low interfacial resistances, both in air and humidified hydrogen atmospheres, were demonstrated. Initial evaluations of the effects of thermal cycles show promising results.

Based on the initial results in Phase I, additional evaluations are planned. The investigations will concentrate primarily on characterizing the metal coupon, both 3 cm diameter and 10 x 10 cm in size, in simulated stack operating conditions. The two main evaluation methods that are planned are outlined below.

Characterization in a Dual Atmosphere: The long-term behavior of the scales will be studied, using 3 cm diameter coupons, when opposite sides are exposed to air and fuel simultaneously at temperature. This test simulates the actual exposure condition of interconnects during fuel cell stack operation. Characterization and improvement of properties are important in evaluation of suitable process development for successful implementation of metal interconnects.

Long Term Electrical Conduction Property Under Stack Operating Conditions: The process selected from the above task will be used to test the long-term properties of the interconnect material in dual atmosphere. In this test, the stainless steel plates of 10 x 10 cm size will be used. After testing the electrical resistance for approximately 200 hours the effect of thermal cycle will be evaluated.

References

1. K. Hilpert et al., "Chapter 74: Interconnects," *Handbook of Fuel Cells – Fundamentals, Technology and Applications,* W. Vielsgtich, A. Gasteiger, and A. Lamm, Eds. Volume 4: *Fuel Cell Technology and Applications*, John Wiley & Sons, Ltd., 2003.
2. G. Meier, "Fundamental Studies of the Durability of Materials for Interconnects in Solid Oxide Fuel Cells," Paper presented at the Fourth SECA Core Technology Workshop, Sacramento, CA, Feb. 19-20, 2003.

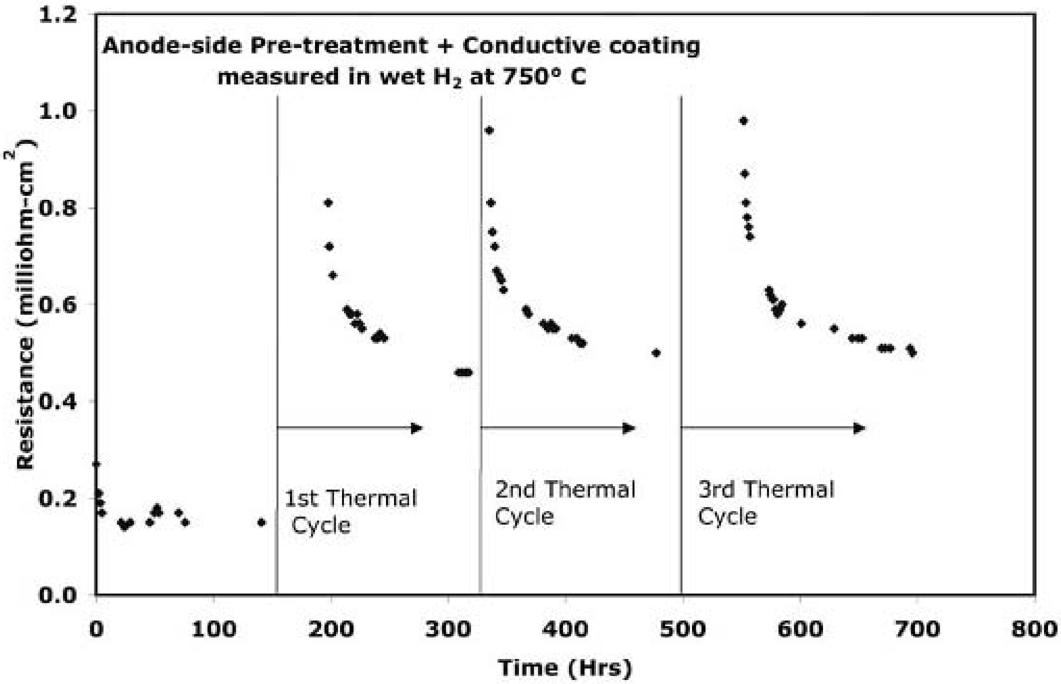

Figure 1. *Stability of treated coupons in humidified hydrogen at 750 ^{o}C.*

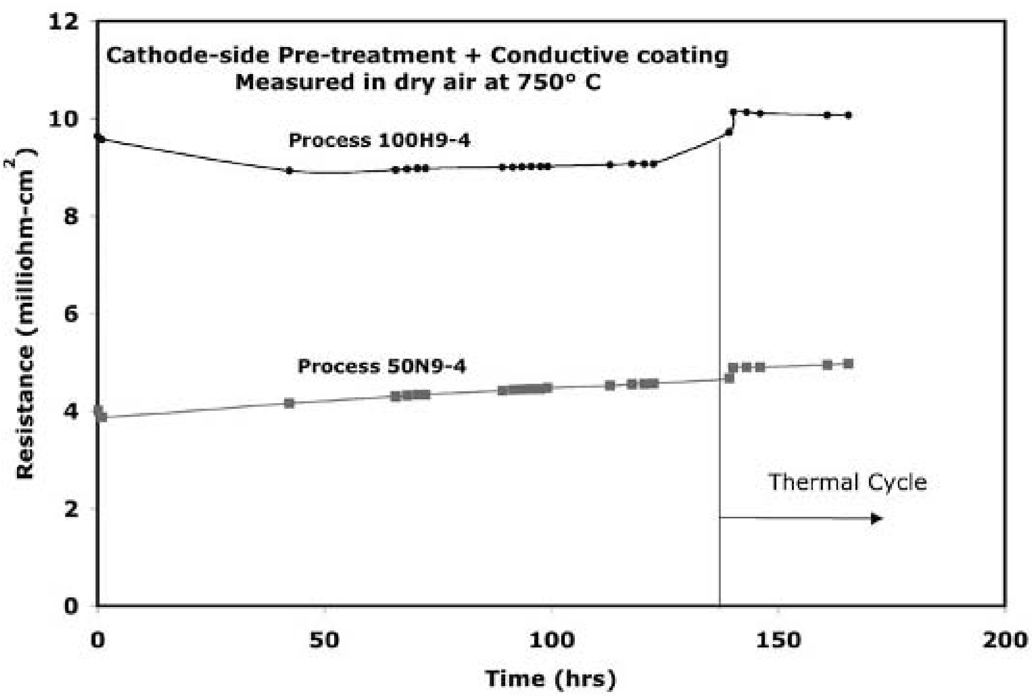

Figure 2. *Stability of treated coupons in air at 750 ^{o}C.*